

E 1.28: SOLAR / 2048 - 79 / 04

Alpha 1214343 (BK)

SOLAR/2048-79/04

Monthly Performance Report



CONCORD LIGHT PLANT

APRIL 1979



U.S. Department of Energy

National Solar Heating and
Cooling Demonstration Program

National Solar Data Program

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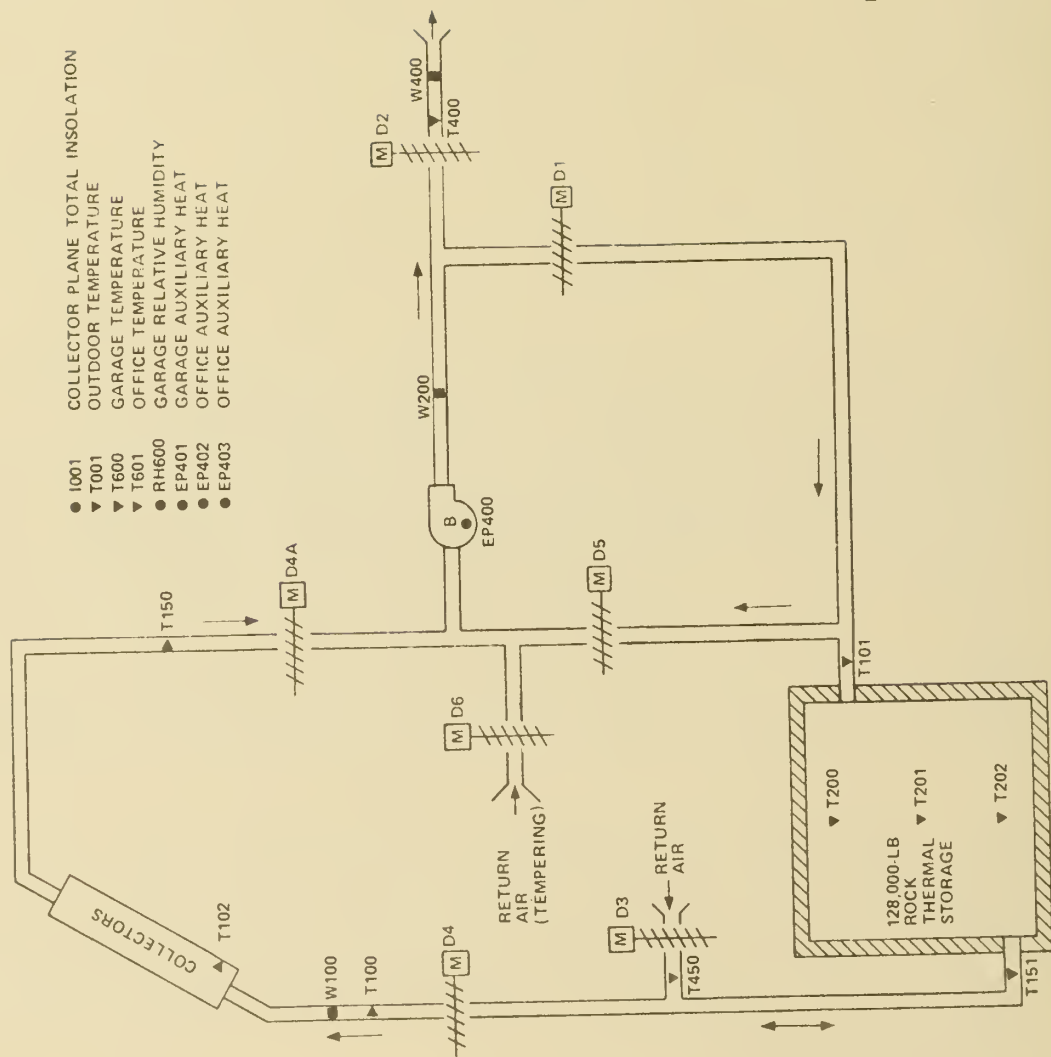
MONTHLY PERFORMANCE REPORT
CONCORD LIGHT PLANT
APRIL 1979

I. SYSTEM DESCRIPTION

The solar energy installation at the Concord Light Plant, Concord, Massachusetts, is an air system that provides space heating for a municipal garage and office area. The system, shown schematically in Figure 1, consists of an array of 92 flat-plate collectors, manufactured by Sunworks, having a gross area of 1,932 square feet. The collector array faces 14 degrees east of south at an angle of 57 degrees from the horizontal. Solar energy is stored in a rock thermal storage bin with a capacity of 1,210 cubic feet. It is located in a corner of the garage. This solar energy system also includes a fan, seven motorized dampers and duct work. Auxiliary energy is provided by electrical resistance heaters rated at approximately 140 kw. The solar energy system is designed to aid in maintaining the garage temperature at 50°F. If any additional energy is available, it is delivered to the office area, which is maintained at approximately 68°F. The system air flow is controlled by six motor-driven dampers. If the solar heated air is too hot for delivery, the seventh damper, which is the tempering damper D6, mixes ambient garage air with the solar heated air. The system has three modes of solar operation.

Mode 1 - Collector-to-Space Heating: In this mode, solar heated air is delivered directly from the collector array to the conditioned space. This will happen whenever there is a demand for space heating and the collector array temperature is higher than the conditioned space or storage temperatures.

Mode 2 - Collector-to-Storage: The system enters this mode whenever the space heating demands have been satisfied and the collector array temperature is higher than the storage temperature. The dampers are positioned to deliver solar heated air directly to storage.



REVISED 2/6/79

Figure 1. CONCORD LIGHT PLANT SOLAR ENERGY SYSTEM SCHEMATIC

Mode 3 - Storage-to-Space Heating: This mode is entered whenever a demand for space heating exists and the collector array temperature is lower than the temperature of the conditioned space. If the storage bin temperature is higher than the temperature of the conditioned space, then heated air is taken directly from storage and circulated through the conditioned space.

II. PERFORMANCE EVALUATION

The system performance evaluations discussed in this section are based primarily on the analysis of the data presented in the attached computer-generated monthly report. This attached report consists of daily site thermal and energy values for each subsystem, plus environmental data. The performance factors discussed in this report are based upon the definitions contained in NBSIR-76-1137, Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program.

A. Introduction

The Concord Light Plant solar energy system was operational throughout the month of April. However, problems in the data collection and processing system resulted in the loss of 19 days of data for the month. Therefore, there are no monthly averages presented for April in this report. It is not feasible to extrapolate averages for a transitional month such as April with only 11 days of data to work with.

The first data loss period occurred from April 1 through April 7, and the second data loss period occurred from April 9 through April 17. Both of these data loss periods were related to problems in the Site Data Acquisition Subsystem (SDAS), and a site visit was made on April 7 and again on April 17 to repair the SDAS. The second site visit on April 17 seemed to correct the SDAS problems, but additional problems of unknown origin caused data to be lost on April 24, 25, and 30.

For the 11 days covered by this report the solar energy system satisfied approximately 90 percent of the space heating energy requirements at the Concord Light Plant. This resulted in a net savings of 3.05 million Btu of electrical energy. A total of 0.77 million Btu of electrical operating energy was required to support the solar energy system.

B. Weather

Because April is a transitional month in the Concord area, both temperature and cloud cover are subject to considerable variation. For April, the long-term average outside ambient temperature for the area is 47°F, and the average insolation incident in the plane of the collector array is 1,239 Btu/ft²-day.

Both the long-term average temperature and insolation values are computed from averages derived from three weather stations in the general area. Two of these are located in the cities of Boston and Natick, and the third is the Blue Hill Observatory, located in Milton. The Blue Hill Observatory station is approximately 10 miles south of the Boston station and at a much higher elevation. It is therefore not subject to the environmental pollutants typical of a large city such as Boston.

C. System Thermal Performance

Collector - During the abbreviated reporting period, a total of 32.68 million Btu of incident solar energy was measured in the plane of the collector array. The system collected 7.88 million Btu, or 24 percent of the total available insolation. During the time when the system was operating, a total of 22.23 million Btu of solar energy was incident on the array. This represents an operational collector efficiency of 35 percent. A total of 0.44 million Btu of electrical energy was required to operate the collector array.

Storage - During the time when the system was operating in the Collector-to-Storage mode, a total of 7.17 million Btu of solar energy was collected. Of this total, 5.72 million Btu were delivered to storage, and consequently, 1.45 million Btu were lost between the collector array and storage. However, approximately 1.16 million Btu of this loss was in the form of leakage past damper D2 and thus served as an uncontrolled heat input to the garage area.

Of the 3.38 million Btu extracted from storage to supply the space heating load, 3.11 million Btu were delivered to the space heating load. The difference of 0.27 million Btu is primarily due to transport losses to the building interior.

The change in stored energy (based only on the daily values, and not the sum printed in the attached computer generated monthly report) was 1.90 million Btu, and this, combined with the energy supplied to and removed from storage, resulted in a thermal loss from storage of 0.44 million Btu. However, due to the data loss problem these storage energy change and loss computations should be viewed with caution. (Approximately 0.01 million Btu of the storage loss was due to thermosiphoning losses through the collector array when the system was off.)

Space Heating Load - The space heating load for the 11 reportable days in April was 4.26 million Btu. Solar energy supplied 3.82 million Btu of this load, and the remaining 0.44 million Btu was supplied by the electrical auxiliary system. This represents a heating solar fraction of 90 percent.

Of the 3.82 million Btu of solar energy supplied to the space heating load, 0.71 million Btu came directly from the collector array and the remaining 3.11 million Btu came from storage. A total of 0.33 million Btu of electrical operating energy was required to deliver solar energy to the space heating load.

The 0.44 million Btu of auxiliary energy required to support the space heating load was all expended in the office area. The solar energy system was able to fully support the garage space heating requirements.

The overall building temperature was maintained at 65.6°F. The average garage temperature was 64.7°F, and the average office temperature was 70.6°F.

D. Observations

In general, the Concord Light Plant solar energy system performed well during the periods for which data were available in April. There were no system problems of any type discovered during this time.

E. Energy Savings

The Concord Light Plant solar energy system realized a gross savings of 3.82 million Btu in the electrical energy requirements for space heating during the report period. However, solar energy was collected and delivered at a cost of 0.77 million Btu in electrical operating energy. The electrical energy net savings for the overall system amounted to 3.05 million Btu.

III. ACTION STATUS

The data loss problem is currently under investigation. It is anticipated that the problem will be isolated by the second week in May.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SITE SUMMARY

SITE: CONCORD LIGHT
REPORT PERIOD: APRIL, 1979

CONCORD, MASS.

SOLAR/9999-79/04

SITE/SYSTEM DESCRIPTION:

THE CONCORD LIGHT SOLAR INSTALLATION PROVIDES SOLAR HEATING FOR THE GARAGE AND OFFICE AREAS OF THE CONCORD MUNICIPAL LIGHT PLANT. THE GARAGE CONTAINS 101,295 CU. FT. AND THE OFFICE SPACE CONTAINS 17,400 CU. FT. THE INSTALLATION IS AN AIR SYSTEM AND HAS 1210 CU. FT. OF ROCK STORAGE. AUXILIARY HEATING IS PROVIDED BY ELECTRICITY WITH 112.5 KW AVAILABLE FOR THE GARAGE AND 29.6 KW AVAILABLE FOR THE OFFICE AREA. TEMPERATURE LEVELS ARE 50F FOR THE GARAGE AND 68F FOR THE OFFICE AREA.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY

COLLECTED SOLAR ENERGY

AVERAGE AMBIENT TEMPERATURE
AVERAGE BUILDING TEMPERATURE
ECSS SOLAR CONVERSION EFFICIENCY
ECSS OPERATING ENERGY
TOTAL SYSTEM OPERATING ENERGY
TOTAL ENERGY CONSUMED

* MILLION BTU
* BTU/SQ.FT.
* MILLION BTU
* BTU/SQ.FT.
* DEGREES F
* DEGREES F
* MILLION BTU
* MILLION BTU
* MILLION BTU

SUBSYSTEM SUMMARY:

LOAD
SOLAR FRACTION
SOLAR ENERGY USED
OPERATING ENERGY
AUX. THERMAL ENERGY
AUX. ELECTRIC FUEL
AUX. FOSSIL FUEL
ELECTRICAL SAVINGS
FOSSIL SAVINGS

HOT WATER
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.

HEATING
*
*
*
*
*
*
N.A.
N.A.
N.A.

COOLING
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.
N.A.

SYSTEM TOTAL
* MILLION BTU
* PERCENT
* MILLION BTU
* MILLION BTU
* MILLION BTU
* MILLION BTU
N.A.
* MILLION BTU
N.A.
* MILLION BTU

SYSTEM PERFORMANCE FACTOR:

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978,
SOLAR/0004-78/18

MONTHLY REPORT
SITE SUMMARY

SITE: CONCORD LIGHT
REPORT PERIOD: APRIL, 1979

SITE/SYSTEM DESCRIPTION:
THE CONCORD LIGHT SOLAR INSTALLATION PROVIDES SOLAR HEATING FOR THE GARAGE AND OFFICE AREAS OF THE CONCORD MUNICIPAL LIGHT PLANT. THE GARAGE CONTAINS 101,295 CU. FT. AND THE OFFICE SPACE CONTAINS 17,400 CU. FT. THE INSTALLATION IS AN AIR SYSTEM AND HAS 1210 CU. FT. OF ROCK STORAGE. AUXILIARY HEATING IS PROVIDED BY ELECTRICITY WITH 112.5 KW AVAILABLE FOR THE GARAGE AND 29.6 KW AVAILABLE FOR THE OFFICE AREA. TEMPERATURE LEVELS ARE 50F FOR THE GARAGE AND 68F FOR THE OFFICE AREA.

GENERAL SITE DATA:
INCIDENT SOLAR ENERGY
COLLECTED SOLAR ENERGY

** GIGA JOULES
 ** KJ/SQ.M.
 ** GIGA JOULES
 ** KJ/SQ.M.
 ** DEGREES C
 ** DEGREES C
 **
 ** GIGA JOULES
 ** GIGA JOULES
 ** GIGA JOULES

AVERAGE AMBIENT TEMPERATURE
AVERAGE BUILDING TEMPERATURE
EXCESS SOLAR CONVERSION EFFICIENCY
EXCESS OPERATING ENERGY
TOTAL SYSTEM OPERATING ENERGY
TOTAL ENERGY CONSUMED

SUBSYSTEM SUMMARY:

SYSTEM SUMMARY.			
	HOT WATER	HEATING	COOLING
LOAD	N.A.	*	N.A.
SOLAR FRACTION	N.A.	*	N.A.
SOLAR ENERGY USED	N.A.	*	N.A.
OPERATING ENERGY	N.A.	*	N.A.
AUX. THERMAL ENG	N.A.	*	N.A.
AUX. ELECTRIC FUEL	N.A.	*	N.A.
AUX. FOSSIL FUEL	N.A.	N.A.	N.A.
ELECTRICAL SAVINGS	N.A.	*	N.A.
FOSSIL SAVINGS	N.A.	N.A.	N.A.

	SYSTEM	TOTAL	GIGA JULES
*	*	PERCENT	
*	*	GIGA JULES	
*	*	GIGA JULES	
*	*	GIGA JULES	
*	*	GIGA JULES	
N.A.	*	GIGA JULES	
N.A.	*	GIGA JULES	

SYSTEM PERFORMANCE FACTOR:

* DENOTES UNAVAILABLE DATA
 @ DENOTES NULL DATA
 N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978,
SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

SITE: CONCORD LIGHT
REPORT PERIOD: APRIL, 1979

CONCORD, MASS.

SOLAR/9999-79/04

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
1	*	*	*	NOT APPLICABLE	*	NOT APPLICABLE	*
2	*	*	*		*		*
3	*	*	*		*		*
4	*	*	*		*		*
5	*	*	*		*		*
6	*	*	*		*		*
7	*	*	*		*		*
8	4.536	37	0.502	NOT APPLICABLE	0.061	NOT APPLICABLE	0.111
9	*	*	*		*		*
10	*	*	*		*		*
11	*	*	*		*		*
12	*	*	*		*		*
13	*	*	*		*		*
14	*	*	*		*		*
15	*	*	*		*		*
16	*	*	*		*		*
17	*	*	*		*		*
18	3.528	43	0.524		0.069		0.149
19	3.162	43	0.671		0.055		0.212
20	3.959	45	0.289		0.060		0.073
21	4.262	47	0.978		0.062		0.229
22	2.273	54	0.243		0.029		0.107
23	4.103	59	0.073		0.066		0.018
24	*	*	*		*		*
25	2.801	65	0.143		0.015		0.051
26	0.299	62	0.000		0.000		0.000
27	2.683	62	0.066		0.017		0.024
28	1.071	57	0.334		0.007		0.312
29	*	*	*		*		*
30	*	*	*		*		*
SUM	*	-	*	N.A.	*	N.A.	-
AVG	*	*	*	N.A.	*	N.A.	*
NBS ID	Q001	N113			Q102		N111

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT COLLECTOR ARRAY PERFORMANCE

SITE: CONCORD, LIGHT REPORT PERIOD: APRIL, 1979
CONCORD, MASS. SOLAR/9999-79/04

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	*	*	*	*	*
2	*	*	*	*	*
3	*	*	*	*	*
4	*	*	*	*	*
5	*	*	*	*	*
6	*	*	*	*	*
7	*	*	*	*	*
8	4.536	4.015	1.467	43	0.323
9	*	*	*	*	*
10	*	*	*	*	*
11	*	*	*	*	*
12	*	*	*	*	*
13	*	*	*	*	*
14	*	*	*	*	*
15	*	*	*	*	*
16	*	*	*	*	*
17	*	*	*	*	*
18	*	*	*	*	*
19	3.528	2.886	0.963	53	0.273
20	3.162	2.538	0.919	53	0.291
21	3.959	2.940	1.140	57	0.288
22	4.262	3.697	1.481	62	0.347
23	2.273	1.026	0.286	67	0.126
24	4.103	3.512	1.068	71	0.260
25	*	*	*	*	*
26	2.801	0.579	0.173	75	0.062
27	0.299	0.000	0.000	63	0.000
28	2.683	0.823	0.288	72	0.107
29	1.071	0.218	0.094	62	0.088
30	*	*	*	*	*
SUM	*	*	*	-	-
AVG	*	*	*	*	*
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT STORAGE PERFORMANCE

SITE: CONCORD LIGHT REPORT PERIOD: APRIL, 1979 CONCORD, MASS. SOLAR/9999-79/04

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORED ENERGY MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	*	*	*	*	*
2	*	*	*	*	*
3	*	*	*	*	*
4	*	*	*	*	*
5	*	*	*	*	*
6	*	*	*	*	*
7	*	*	*	*	*
8	*	*	*	*	*
9	0.904	0.138	0.956	80	1.209
10	*	*	*	*	*
11	*	*	*	*	*
12	*	*	*	*	*
13	*	*	*	*	*
14	*	*	*	*	*
15	*	*	*	*	*
16	*	*	*	*	*
17	*	*	*	*	*
18	0.773	0.575	0.161	79	0.952
19	0.749	0.727	0.067	83	1.060
20	0.918	0.284	0.810	87	1.192
21	1.014	0.863	0.269	97	1.116
22	0.230	0.262	-0.317	105	-0.238
23	0.794	0.082	0.688	117	0.970
24	*	*	*	*	*
25	0.131	0.163	-0.190	*	0.497
26	0.000	0.000	-0.098	130	1.000
27	0.173	0.000	-0.055	128	-0.139
28	0.031	0.000	-0.024	126	-2.392
29	*	0.290	-0.364	120	*
30	*	*	*	*	*
SUM	*	*	4.762	-	-
AVG	*	*	0.159	*	*
NBS ID	Q200	Q201	Q202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SPACE HEATING SUBSYSTEM

SOLAR/9999-79/04

SITE: CONCORD LIGHT
REPORT PERIOD: APRIL, 1979

CONCORD, MASS.

DAY OF MON.	SPACE HEATING LOAD MILLION BTU	SOLAR FR.OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG TEMP DEG. F	AMB TEMP DEG. F
1	**	**	**	**	**	**	**	**	**	**	**
2	**	**	**	**	**	**	**	**	**	**	**
3	**	**	**	**	**	**	**	**	**	**	**
4	**	**	**	**	**	**	**	**	**	**	**
5	**	**	**	**	**	**	**	**	**	**	**
6	**	**	**	**	**	**	**	**	**	**	**
7	**	**	**	**	**	**	**	**	**	**	**
8	0.613	82	0.502	0.022	0.111	0.111	NOT APPLICABLE	0.479	NOT APPLICABLE	58	37
9	**	**	**	**	**	**	**	**	**	**	**
10	**	**	**	**	**	**	**	**	**	**	**
11	**	**	**	**	**	**	**	**	**	**	**
12	**	**	**	**	**	**	**	**	**	**	**
13	**	**	**	**	**	**	**	**	**	**	**
14	**	**	**	**	**	**	**	**	**	**	**
15	**	**	**	**	**	**	**	**	**	**	**
16	**	**	**	**	**	**	**	**	**	**	**
17	**	**	**	**	**	**	**	**	**	**	**
18	0.580	90	0.524	0.048	0.056	0.056	NOT APPLICABLE	0.476	NOT APPLICABLE	62	43
19	0.746	90	0.671	0.076	0.075	0.075	NOT APPLICABLE	0.595	NOT APPLICABLE	64	43
20	0.360	80	0.289	0.054	0.071	0.071	NOT APPLICABLE	0.235	NOT APPLICABLE	64	45
21	1.053	93	0.978	0.075	0.076	0.076	NOT APPLICABLE	0.903	NOT APPLICABLE	68	47
22	0.261	93	0.243	0.017	0.019	0.019	NOT APPLICABLE	0.226	NOT APPLICABLE	64	54
23	0.098	75	0.073	0.006	0.024	0.024	NOT APPLICABLE	0.068	NOT APPLICABLE	68	59
24	**	**	**	**	**	**	**	**	**	**	**
25	**	**	**	**	**	**	**	**	**	**	**
26	0.143	100	0.143	0.007	0.000	0.000	NOT APPLICABLE	0.136	NOT APPLICABLE	70	65
27	0.002	0	0.000	0.000	0.002	0.002	NOT APPLICABLE	0.000	NOT APPLICABLE	67	62
28	0.066	100	0.066	0.002	0.000	0.000	NOT APPLICABLE	0.064	NOT APPLICABLE	69	62
29	0.334	100	0.334	0.023	0.000	0.000	NOT APPLICABLE	0.311	NOT APPLICABLE	68	57
30	**	*	*	*	*	*	*	*	*	*	*
SUM	**	-	*	*	*	*	N.A.	*	N.A.	-	-
AVG	**	*	*	*	*	*	N.A.	*	N.A.	*	*
NBS	Q402	N400	Q400	Q403	Q401		Q410	Q415	Q417	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT ENVIRONMENTAL SUMMARY

SOLAR/99999-79/04

SITE: CCNCORD LIGHT
REPORT PERIOD: APRIL, 1979

CONCRD, MASS.

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	*	NOT	*	*	*	NOT	NOT
2	*	APPLICABLE	*	*	*	APPLICABLE	APPLICABLE
3	*		*	*	*		
4	*		*	*	*		
5	*		*	*	*		
6	*		*	*	*		
7	*		*	*	*		
8	2348		37	43	31		
9	*		*	*	*		
10	*		*	*	*		
11	*		*	*	*		
12	*		*	*	*		
13	*		*	*	*		
14	*		*	*	*		
15	*		*	*	*		
16	*		*	*	*		
17	*		*	*	*		
18	1826		43	53	28		
19	1636		43	53	25		
20	2049		45	57	23		
21	2206		47	62	24		
22	1177		54	67	26		
23	2123		55	71	22		
24	*		*	*	*		
25	*		*	*	*		
26	1450		65	75	33		
27	155		62	73	60		
28	1389		57	62	51		
29	554		*	*	49		
30	*		*	*	*		
SUM	*	N.A.	-	-	-	-	-
AVG	*	N.A.	*	*	*	N.A.	N.A.
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.

@ DENOTES NULL DATA.

N.A. DENOTES NOT APPLICABLE DATA.



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